Virginia City Hybrid Energy Center
Response to Data Request
Vivian Thomson, Vice Chair, Virginia Air Pollution Control Board

Question (Page No. 3):

How much mercury will be deposited in the North Fork of the Holston River as a result of Virginia City Hybrid Energy Facility's emissions? How much additional mercury will be deposited in other Virginia waterways as a result of this facility's emissions?

Response:

VCHEC has evaluated the potential impacts of mercury emissions and subsequent deposition to the closest watershed, the Clinch River. The methods and results of this analysis are presented in the attached memorandum (Attachment 1). The analysis is conservative in several ways and predicts that the incremental concentrations of mercury in both water and fish tissue are very low. In fact, despite the very conservative nature of the analysis, the model predicts mercury concentration in fish tissue to be less than one percent of the US EPA Water Quality Criterion for mercury in fish tissue.

While a separate analysis was not performed for the North Fork of the Holston River, the average rate of mercury deposition in these watershed will be lower than that received by the Clinch River catchment. For that reason, should a separate analysis be performed, the predicted incremental impacts would be lower in the North Fork of the Holston than in the Clinch River. Incremental concentrations in other more distant water bodies would be substantially lower given that the majority of atmospheric deposition occurs within approximately 10 km of the source. A conservative screening-level modeling analysis of airborne emissions from the proposed Virginia City Hybrid Energy Center (VCHEC) has been conducted to assess the potential long-term average incremental mercury water column and predicted fish tissue concentrations in the nearby rivers of southwest Virginia. The analysis is attached.

ATTACH ENT 1

Memorandum

Date: April 22, 2008

To: Bob Bisha / Dominion

From: David Heinold, Amanda MacNutt, Steve Cibik, Mark Gerath, Kristen Durocher / ENSR

Subject: Mercury Modeling in SW Virginia Watersheds

Distribution: Bill Campbell

ENSR conducted a conservative screening-level modeling analysis of airborne emissions from the proposed Virginia City Hybrid Energy Center (VCHEC) to assess the potential long-term average incremental mercury water column and fish tissue concentrations in the nearby rivers of southwest Virginia. A review of topographic maps of the region identified two major river systems passing within 25 km of the proposed facility. The Clinch River passes within 5 km of VCHEC and the Holston River, at its closest point, is about 20 km distant. Due to its proximity, the Clinch River watershed would likely receive more deposition of mercury from VCHEC. Given that the watershed characteristics (e.g., typical slopes, precipitation patterns, etc.) of the two river systems are similar, the screening analysis was conducted for the Clinch River and the modeled impacts considered to be conservatively representative of all rivers in the area (i.e., concentrations in the Clinch River would likely be higher than those in other, more distant rivers).

Incremental water concentrations were calculated for the Clinch River near the proposed VCHEC at a location that receives runoff from terrain to the east where, due to prevailing winds, maximum rates of deposition are predicted to occur. The analysis followed conservative assumptions recommended in the 2005 Final U.S. EPA's Human Health Risk Assessment Protocol ("HHRAP"). HHRAP incorporates advances in science that the U.S. EPA has made through conducting and reviewing risk assessments for combustion sources. Because it is part of a regulatory program, HHRAP includes conservative assumptions and methodologies to help ensure that estimates of media concentrations are conservatively high.

To conduct this assessment, the Industrial Risk Assessment Program (IRAP), which implements HHRAP guidance, was applied. IRAP is not a dispersion or deposition model, but uses externally estimated deposition rates. Air quality modeling for the proposed power plant has been conducted (by TRC) using CALPUFF. The modeled concentrations for this project from the CALPUFF simulations were applied to conservatively estimate mercury deposition on the Clinch River watershed. IRAP was then used to estimate the transport of mercury through the watershed and the predicted incremental concentration of mercury in the Clinch River. The following is the sequence of steps employed during the analysis:

1. Define the watershed upstream of the exposure point of interest

Figure 1 shows the extent of the Clinch River watershed upstream of VCHEC that was delineated for the analysis. The location in the watershed along the river which is closest to the proposed power plant is the point at which the mercury water column concentration was assessed. Note that modeled predictions of deposition were only available for a portion of the upstream watershed located out to 42 km from the plant. The mercury deposition and runoff in the portion of the watershed within the modeling domain was simulated. This produced estimates of streamflow and mercury loading that are consistent and are likely to overestimate waterborne mercury in the river, because the upper watershed experiences runoff per unit area similar to the lower watershed but receives lower incremental mercury loadings due to the increased distance from the plant.

2. Compute the deposition of mercury on the watershed

Modeled annual average emission-normalized concentrations (i.e., for a 1 g/sec emission rate) were obtained from TRC for three years (2001-2003). The CALPUFF modeling used a rectangular nested grid with 100 m spacing out to 3 km, 250 m spacing out to 8 km, 500 m spacing out to 18 km, and 1km spacing out to 42 km (see Figure 2). IRAP requires that the watershed be represented by equally-spaced receptors in a rectangular grid so that it can calculate the total deposition on the watershed. This required that model results be selected from a subset of receptors modeled, spaced 1 km apart within the watershed area. Figure 3 depicts watershed, water body (Clinch River), and receptor locations used in IRAP. The risk receptor indicated in the figure denotes the location where IRAP calculated the total water column concentration. Note that because the maximum extent of the CALPUFF receptors extended to 42 km, only the western half of the Clinch River watershed was modeled. As noted above this is not a significant limitation to this assessment because a compensating adjustment was made to watershed runoff, and the modeled deposition rates are very small at 42 km and rapidly diminish with distance.

To compute deposition to the watershed IRAP requires the dry and wet long-term average emission-normalized deposition values for each watershed receptor. Although the effect of deposition is to attenuate the concentration with downwind distance, for this application it was conservatively assumed that there is no attenuation and that the long-term dry deposition rate to the watershed is equal to the long-term concentration multiplied by a deposition velocity of 2.9 cm/sec, which is recommended by HHRAP. The technical discussion in HHRAP notes that value is an upper-limit estimate of the deposition velocity. To estimate long-term emission-normalized concentrations, the average CALPUFF concentration at each watershed receptor was computed by averaging over the three modeled years.

Given that CALPUFF also does not estimate wet deposition of mercury, wet deposition was estimated as a percentage of dry deposition. The ratio of wet to dry deposition is typically highest at receptors adjacent to tall stacks (where ground-level concentrations and dry deposition are negligible), but at greater distances, where the plume reaches the ground, the modeled wet mercury deposition is a small fraction of the modeled dry deposition. In this case the closest watershed receptors are about 2 km from the stack. In recent IRAP applications conducted by ENSR where both dry and wet mercury deposition was explicitly modeled, the wet deposition was only about 1 to 2% of the dry deposition at 2 km and beyond. To ensure conservatism for this application the wet deposition was set to 10% of the dry deposition.

3. Compute mercury concentration in water

In addition to the dry and wet deposition at each receptor, other site-specific input parameters entered into IRAP as required by HHRAP are listed in Table 1. The total mercury emission rate entered into IRAP is 72 lb/year, which is based on proposed permit limits. This emission rate was then partitioned into elemental mercury (vapor) and divalent mercury (both vapor and particulate). Based on the EPRI publication, “An Assessment of Mercury Emissions from U.S. Coal-Fired Power Plants” (EPRI Technical Report 1000608, October 2000), elemental mercury speciation for this project was estimated to be approximately 83% of the total mercury emissions. For the remaining 17% of emitted mercury which is in the divalent form, following the apportionment of divalent mercury emissions into particles and vapor by EPA in HHRAP, it was assumed that 75 percent of the emitted divalent mercury is vapor and 25 percent is particulate. HHRAP also establishes the fraction of each mercury species emitted that enters the global cycle and, therefore, is not subject to deposition. Table 2 shows the phase allocation and speciation of mercury in air as specified by HHRAP. The speciated mercury emissions input to IRAP (as computed in Table 2) are provided in Table 3. The resultant total incremental water column concentrations (average over 30 years and maximum after 30 years) of mercury modeled by IRAP at the risk receptor location shown in Figure 3 are provided in Table 4.

4. Comparison of modeled incremental concentrations to ambient water concentrations

In February, 2007, ENSR conducted a limited study of ambient conditions in the study area, including measurements of total and dissolved mercury concentrations in three samples collected from the Clinch River. These concentrations ranged from 4.25E-07 to 5.30E-07 mg/L (0.425 and 0.53 ng/L), two orders of magnitude higher than the incremental contribution modeled in IRAP. Table 5 summarizes the results of the modeled mercury concentrations, the ambient concentrations from February 2007, and theoretical total concentrations (ambient plus incremental) for both average and maximum conditions. It should be noted that the mercury concentrations in portions of the North Fork of the Holston River are much higher due to direct historical contamination from a chlor-alkali plant that is now a Superfund site.

The lowest Virginia Water Quality Standard (WQS) for mercury is 50 ng/L (for protection of public water supplies). For aquatic organisms, the WQS is 770 ng/L of dissolved mercury in the water column. The measured mercury concentrations from the 2007 sampling were two orders of magnitude below the lowest WQS. The calculated incremental mercury concentrations in the Clinch River are two orders of magnitude lower than the ambient measured concentrations, resulting in essentially unchanged ambient water column levels. IRAP was also used to estimate the concentration of methyl mercury in fish tissue.

5. Fish Advisories

The model estimated a mercury fish concentration of about 3.2×10^{-3} mg Hg per Kg fresh weight fish tissue, less than one percent of available fish tissue data for mercury in the Clinch River. Virginia DEQ conducts fish tissue sampling studies on a regular basis to determine which of the waters in the state require fish advisories for mercury and other bioaccumulative compounds (e.g., PCBs). Mercury concentrations in fish tissue were available for three locations on the Clinch River from 1997, and two on the Clinch River from 2002. Concentrations of mercury in all the fish from these studies met the U.S. EPA (2007) Methylmercury AWQC for human health (0.3 mg/kg methylmercury in fish tissue), thus there are no fish advisories for mercury in the Clinch River. A summary of the available data is presented in Table 6. Additional data from the Guest River in the Clinch River Basin were found for 2003. These concentrations are similar to or lower than the data collected from the Clinch River in 1997 and 2002, and are presented for reference in Table 7.

6. Summary

Incremental contributions of atmospheric mercury to the Clinch River from the operation of the proposed VCHEC were conservatively estimated using U.S. EPA-approved modeling methods. Modeled incremental concentrations in the Clinch River were shown to be two orders of magnitude lower than current ambient conditions. These modeling results show that average mercury concentrations in the Clinch River will increase by less than one percent as a result of the operation of the VCHEC. Predicted fish tissue concentrations are also very low compared to the US EPA thresholds for mercury in fish tissue.

These predictions are very useful for the prediction of mercury in water and fish tissue in the North Fork of the Holston River. Based on the distance from the VCHEC and the prevailing wind directions, mercury deposition rates will be higher in the Clinch River watershed indicating that the incremental concentrations of mercury in water and fish will be lower in the Holston River. Thus, the conservatively predicted incremental mercury concentration in fish is less than one percent of the US EPA threshold of 0.3 mg/kg.

Figure 1 Clinch River Watershed Upstream of VCHEC

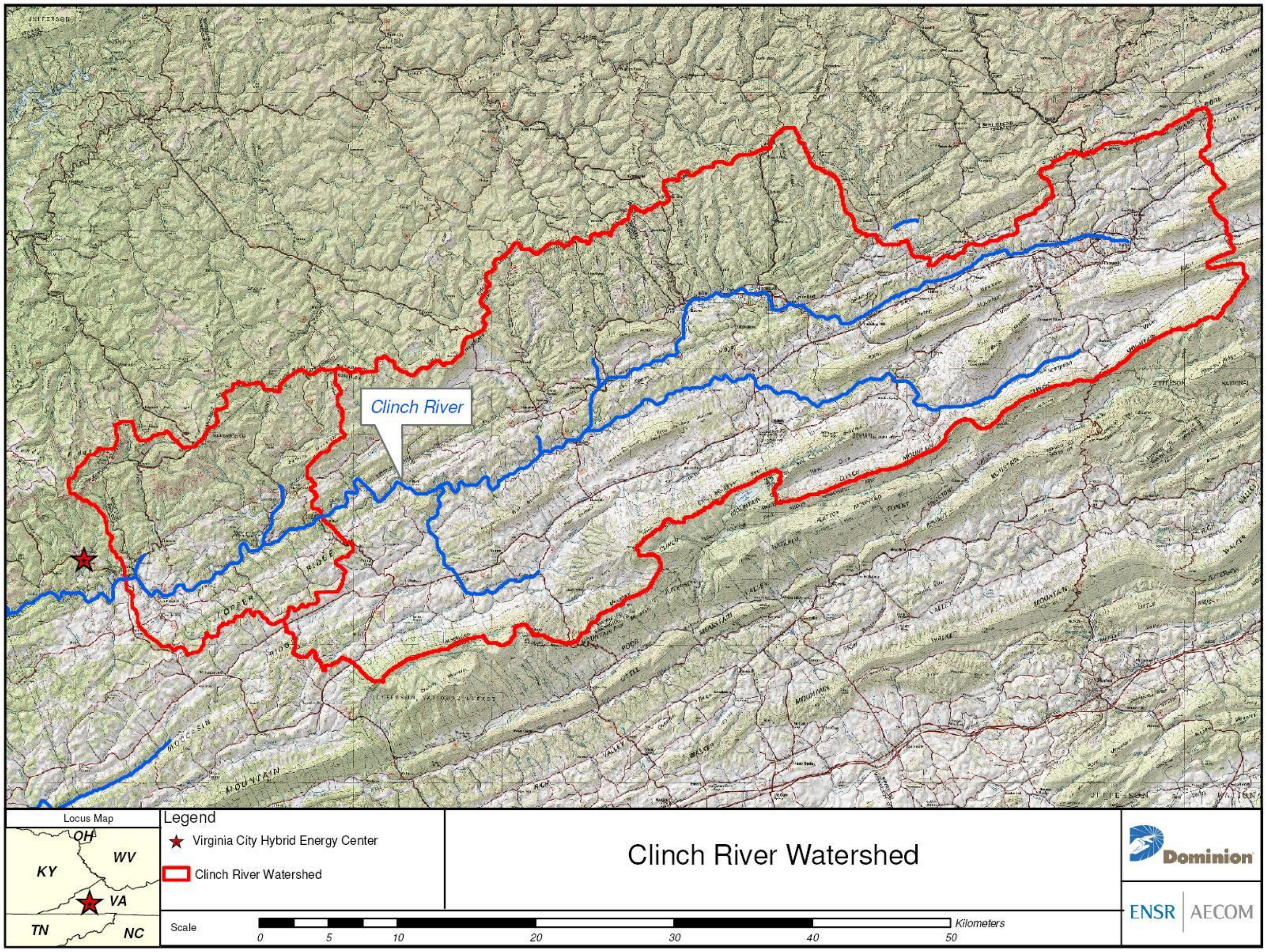

Figure 2 Receptor Locations (Provided by TRC) Relative to Clinch River Watershed

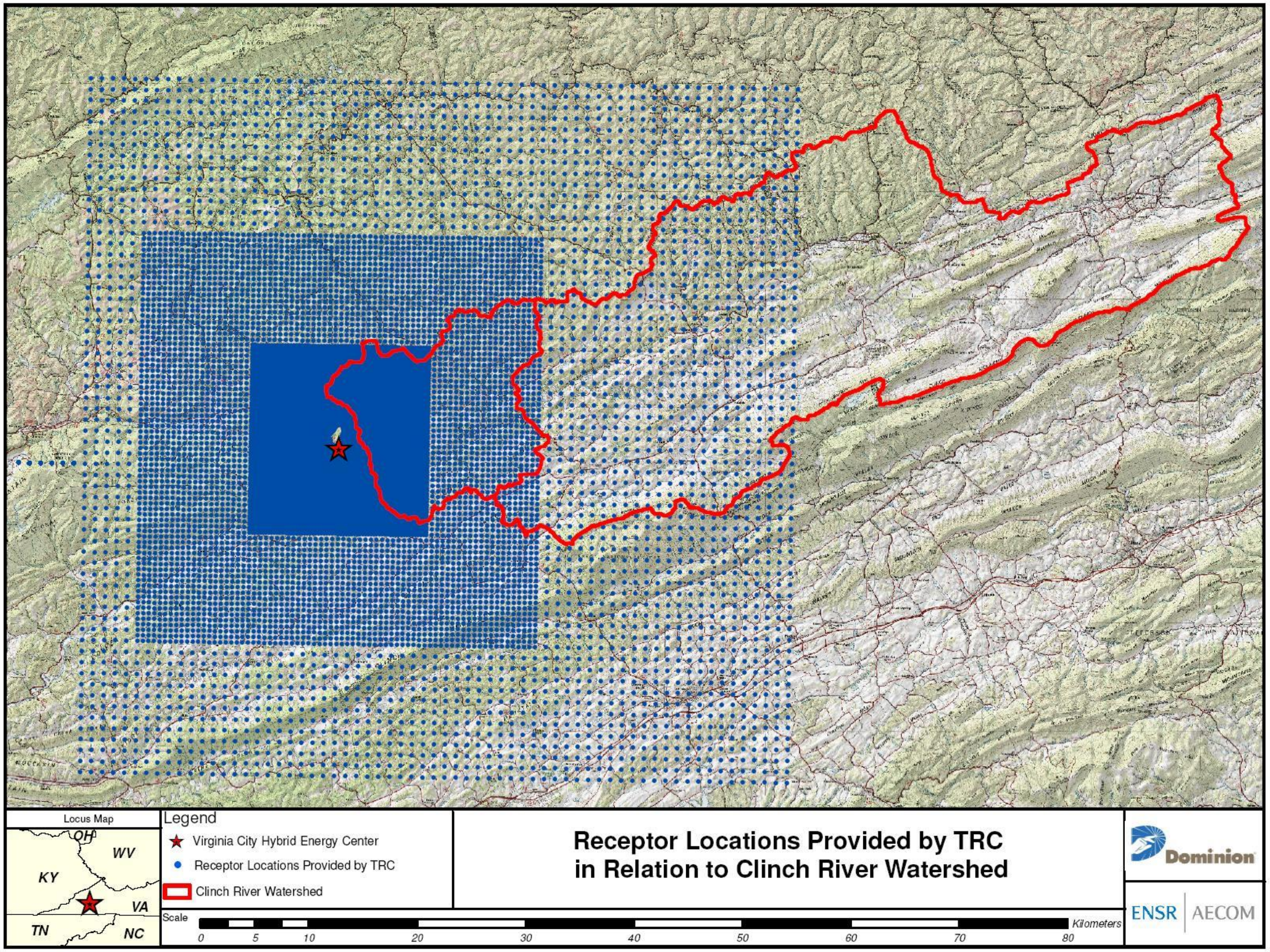

Figure 3 Watershed, Waterbody, and Receptor Location Input to IRAP

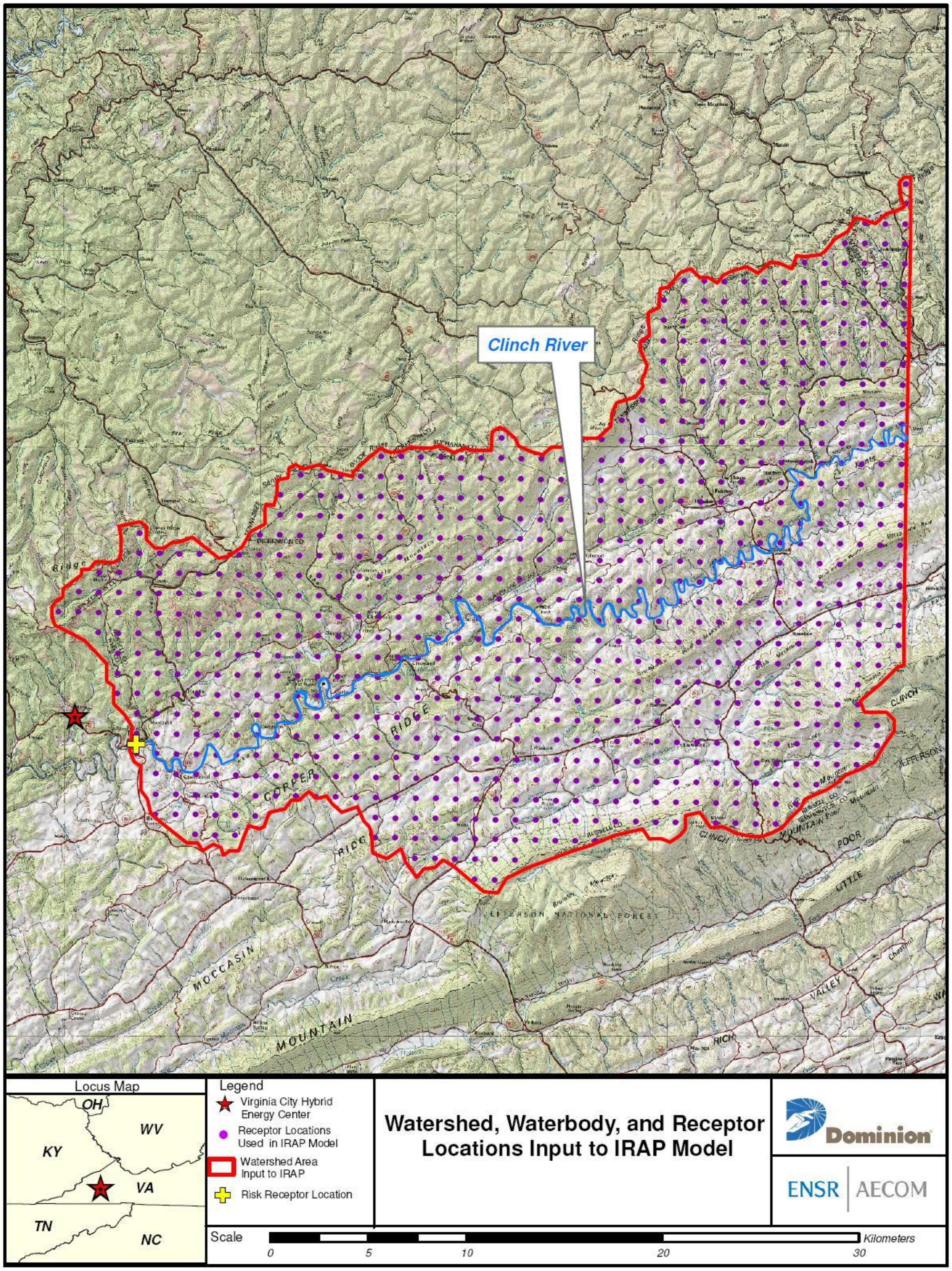

Table 1 Site-specific Parameters Input to IRAP

	Parameter	Units	Value	Reference
General Information	Time of Deposition	(years)	30	Used in previous risk assessments.
	Average Annual Precipitation	(cm/yr)	111.8	Climate of the United States, Volume 2.
	Average annual surface runoff	(cm/yr)	45.7	Georeferenced contours obtained electronically from USGS, developed from "Average annual runoff in the United States, 1951-80" Gebert, W. A.; Graczyk, David J.; Krug, William R
	Average Annual Evapotranspiration	(cm/yr)	26.5	From UVA Climatology Office: Burkes Garden, 24.47 in/yr total and Pennington Gap, 28.53 in/yr total.
	Average Annual Irrigation	(cm/yr)	1.1	Calculated based on Estimated Water Use in the United States, 2000. For the State of Virginia, irrigated land withdrawals were 29,600 acre-feet per year in 2000, with an application rate of 0.38 acre-feet per acre. This is based on a total irrigated land area of 78,200 acres in Virginia. Dividing the irrigate land water withdrawals by the total irrigated land area results in an average annual irrigation rate of 0.38 feet/year, or 4.5 inches/year.
	Rainfall Erosivity Factor	($year^{-1}$)	200	Wise County, VA averaged from RUSLE2, US Department of Agriculture.
	Average Annual Temperature at Bristol, TN	(^{o}C)	13.3	Climate of the United States, Volume 2.
	Avg Annual Wind Speed at Bristol, TN	(m/s)	2.5	Climate of the United States, Volume 2.

Table 1 Cont.

Clinch River	USLE Cover Management Factor	unit less	0.1	EPA recommended value for grass and crops (HHRAP, 2005)
	Pervious Watershed Area	(m^2)	8.76E+08	Assuming 100% pervious
	Impervious Watershed Area	(m^2)	0.00E+00	Assuming 100% pervious
	Total Clinch River Watershed Area	(m^2)	8.76E+08	Delineated area around modeled receptors. Note that just the western portion of the actual watershed was used as modeled receptors did not extend through entire Watershed area.
	Average Clinch River Flow	(m^3/y)	5.98E+08	Period of record daily average flow recorded at Clinch River at Dungannon, USGS gage 03524000 = 711 cfs (6.25E08 m^3/year) as of April 2007.
	Clinch River Current Velocity	(m/s)	0.36	Averaged cross-sectional velocity of 1.17 fps (0.36 m/sec) from multiple measurements of water velocity at the Clinch River at Dungannon, USGS gage 03524000, between April 1999 and April 2007.
	Clinch River Surface Area	(m^2)	6.09E+06	Delineated area in IRAP, based on USGS 1:24,000 topographic map. Note that just the western portion of the river was used as modeled receptors did not extend through entire watershed area.
	Average Length of Clinch River	(m)	19697.0	Measured in GIS using USGS National Hydrologic Dataset 1:100K.
	Average Width of Clinch River	(m)	37.0	Average width of 122 feet (37.2 meters) from multiple measurements of water velocity in the Clinch River at Dunganonn, USGS gage 03524000, between April 1999 and April 2007.
	Average Depth of Clinch River	(m)	1.4	Calculated by dividing the average cross-sectional area (53 square meters) by the average width (37.2 meters). The average cross-sectional area of 572 square feet (53 square meters) from multiple measurements of the wetted cross-section in the Clinch River at Dungannon, USGS gage 03524000, between April 1999 and April 2007.

Table 2 HHRAP Phase Allocation and Speciation of Mercury in Air

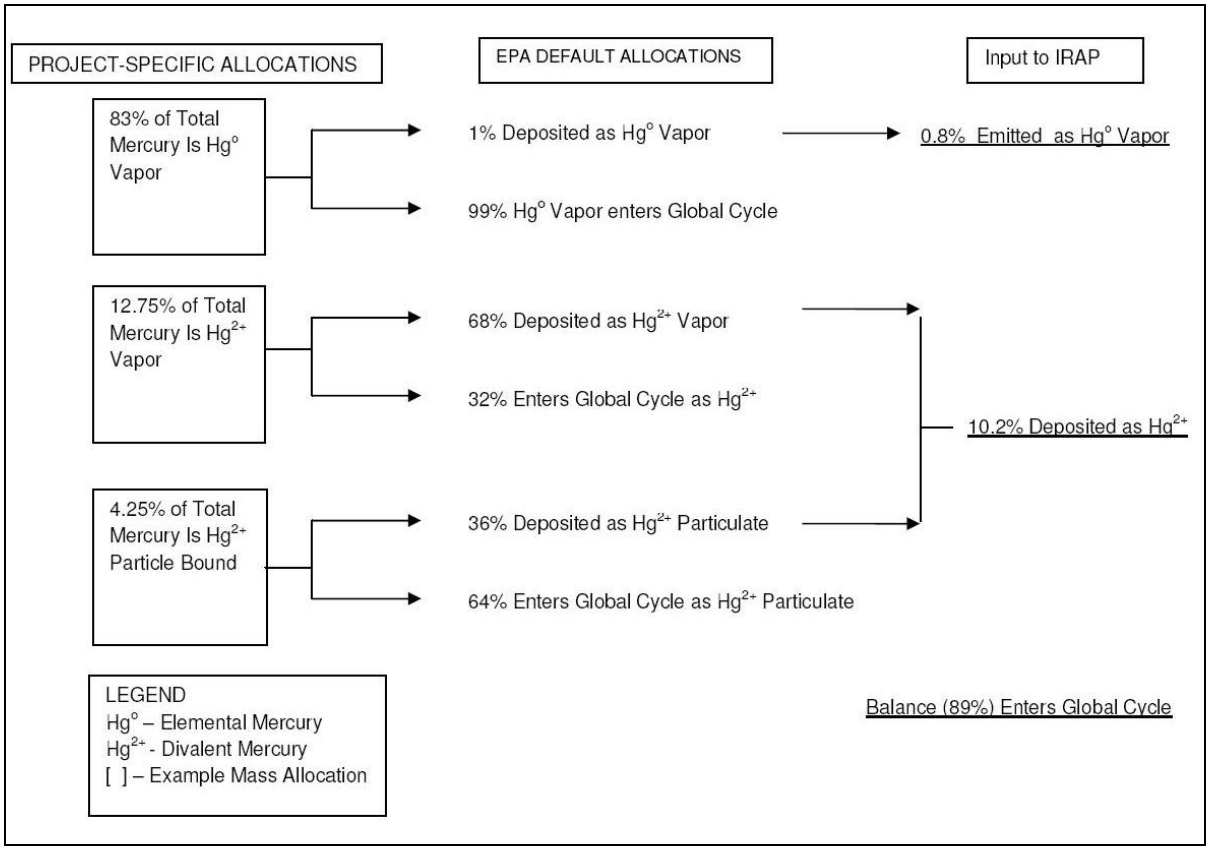

Table 3 Speciated Mercury Emissions Used in IRAP to Compute Deposition

HAP	Emission Rate* (g/sec)
Elemental Mercury (Hg^0)	8.24E-06
Divalent Mercury (Hg^{2+})	1.05E-04

* According to calculations shown in Table 2, based on total Hg emission rate of 1.03E-03 g/sec.

Table 4 Incremental Mercury Concentrations in Water Column from IRAP Model

HAP	Total Water Column Concentration[1] Average (mg/L water)	Total Water Column Concentration[1] Maximum (mg/L water)
Mercury II (Inorganic Mercury)	3.27E-09	6.24E-09

(1) Concentration dissolved in water plus concentration associated with suspended solids

Table 5 Mercury Concentrations in Water Column

Source of Mercury Concentration	Total Water Column Concentration[1] Average (ng/L water)	Total Water Column Concentration[1] Maximum (ng/L water)
IRAP (Inorganic Mercury)	0.00327	0.00624
February 2007 Sampling (Total Mercury)	0.478[(2)]	0.530
Total Mercury[(3)]	0.481	0.536

(1) Concentration dissolved in water plus concentration associated with suspended solids
(2) Average of both February 2007 samples from the Clinch River
(3) Sum of ambient concentrations and IRAP incremental concentrations.

Table 6 Mercury Concentrations in Fish Tissue from the Clinch River

Year	Sample Location	Fish Species	N(1)	Range of Length (cm)	Range of Weight (g)	Mercury (mg/kg)(2)
1997	Clinch River near Clinchport [DEQ Rivermile 6BCLN211.00]	Golden redhorse sucker	20	28.0-60.5	205-1830	0.30
		Rock bass	20	11.0-16.5	26.2-91.0	0.077
		Longear sunfish	11	9.0-13.5	13.2-70.2	0.061
		Smallmouth bass	8	13.5-30.5	35-200	0.15
		Gizzard shad	3	35.0-38.0	500-635	0.031
	Clinch River near Dungannon [DEQ Rivermile 6BCLN236.00]	Golden redhorse sucker	2	30.0-31.5	280-700	0.11
		Gizzard shad	8	29.0-37.5	290-600	0.029
		Smallmouth bass	6	23.0-31.0	150-310	0.21
	Clinch River near Carbo [DEQ Rivermile 6BCLN264.96]	Sunfish species	6	10.0-17.5	21.8-109.6	<0.01
		Stoneroller	9	11.5-13.0	17.3-32.3	<0.01
		Northern hogsucker	3	20.5-27.0	100-220	<0.01
		Rock bass	13	13.5-19.5	51.5-135.8	0.14
		Golden redhorse sucker	2	35	310-570	0.063
2002	Clinch River near Dungannon [DEQ Rivermile 6BCLN236.00]	Smallmouth bass	8	22.2-28.8	122-316	0.082
		Rock bass	5	19.2-22.0	152-212	0.066
		Rock bass	10	15.7-18.8	80-146	0.032
		Golden redhorse sucker	2	68.7-69.8	3608-3768	0.25
		Golden redhorse sucker	3	57.4-65.5	2340-3038	0.17
	Clinch River near Clinchport [DEQ Rivermile 6BCLN211.00]	Smallmouth bass	5	24.5-32.7	186-402	0.14
		Rock bass	6	15.0-19.4	64-128	0.036
		Golden redhorse sucker	3	55.2-60.0	1798-2476	0.21
		Golden redhorse sucker	2	38.5-40.9	660-790	0.15

Notes:

All data obtained from VDEQ website [http://www.deq.virginia.gov/fishtissue/fishtissue.html]
(1) N = number of individuals in sample
(2) Wet weight

Table 7 Mercury Concentrations in Fish Tissue from the Guest River

Year	Sample Location	Fish Species	N(1)	Range of Length (cm)	Range of Weight (g)	Mercury (mg/kg)(2)
2003	Guest River near Bangor; near confluence with Clinch River [DEQ Rivermile 6BGUE000.23]	Rock bass	3	17.8-21.3	98-200	0.076
		Redhorse sucker	5	39.0-43.5	418-632	0.243
		Largemouth bass	1	26.5	220	0.236
	Guest River near Rt.72 bridge; downstream of Coeburn [DEQ Rivermile 6BGUE006.50]	Carp	1	73.5	6400	0.146
		Rock bass	3	18.0-22.0	120-222	0.107
		Smallmouth bass	5	24.4-27.2	182-256	0.119
		Northern hogsucker	5	27.6-31.3	240-384	0.093
	Guest River near Rt. 658; upstream of Coeburn [DEQ Rivermile 6BGUE009.33]	Rock bass	4	14.1-17.8	60-114	0.105
		Redbreast sunfish	5	12.3-17.3	42-104	0.078
		Carp	1	54.7	2126	0.143
		Carp	1	63.5	3474	0.134
		Carp	1	56.7	2344	0.138
		Carp	1	50.5	1842	0.126
		Carp	1	63.7	4414	0.084
		Carp	1	59.0	2960	0.139
		Northern hogsucker	5	19.1-24.7	72-148	0.064
	Guest River near Tacoma [DEQ Rivermile 6BGUE014.49]	Smallmouth bass	2	20.5-25.6	104-206	0.122
		Largemouth bass	1	34.8	658	0.295
		Redbreast sunfish	5	15.3-17.7	76-112	0.073
		Carp	1	60.2	2894	0.108
		Carp	1	60.0	2714	0.147
	Guest River near Hawthorne [DEQ Rivermile 6BGUE020.37]	Redbreast sunfish	4	15.1-18.2	72-134	0.067
		Rock bass	4	19.5-22.9	144-246	0.112
		Northern hogsucker	3	21.4-26.2	110-232	0.119
		Carp	1	65.1	4162	0.237
		Carp	1	56.9	2484	0.095
	Guest River near Lipps [DEQ Rivermile 6BGUE029.14]	Rock bass	5	16.9-20.4	100-162	0.079
		Northern hogsucker	7	15.0-17.9	30-58	0.050

Notes:

All data obtained from VDEQ website [http://www.deq.virginia.gov/fishtissue/fishtissue.html]

(1) N = number of individuals in sample

(2) Wet weight